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POWER CONSUMPTION OF NETWORK TECHNOLOGIES IN MODERN SMARTPHONES

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Abstract

The thesis was assigned by Versine Ltd. and the purpose was to study real-world power consumption of network technologies in modern smartphones. It was measured by connecting the devices to an external voltage source and measuring voltage and amperage independently. Network technologies used were 2G, 3G and Wi-Fi.

The power consumption of the specific network technologies was controlled by first measuring the device's power consumption in airplane mode, when all the radio circuits are turned off. The devices were then configured in ways that allowed them to only make a network connection using the desired technology.

Measurements were made utilizing maximal transmission and reception bandwidth and also in idle mode. Measurements were also made in varying signal strength conditions.

The result of the thesis was that idling on a Wi-Fi or 3G networks uses just as much as transmitting data. In most cases transmission used less energy than idling. 2G was found to be an order of magnitude worse and drawing up to 18 times more power than Wi-Fi or 3G.

Keywords
mobile devices, wireless technology, energy efficiency

Miscellaneous

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Tiivistelmä

Versine Oy:n tilaaman tutkimuksen tarkoitus oli verkkoteknologioiden käytännön tehonkulutuksen mittaaminen älypuhelimissa. Puhelimet kytkettiin tasajännitelähteeseen ja niiden käyttämä teho mitattiin VA-mittauksella. Mitatut teknologiat olivat 2G, 3G sekä Wi-Fi.

Verkkoteknologioiden tehonkulutus eristettiin mittaamalla puhelimien tehonkulutus ensin lentokonetilassa, jolloin radiolähettimet olivat pois päältä ja sen jälkeen muuttamalla puhelimen asetuksia siten, että puhelimet saatiin muodostamaan yhteys halutulla teknologialla.

Mittaukset tehtiin tyhjäkäyntitilassa sekä maksimaalisilla lähetys- ja vastaanottokaistoilla useissa eri signaaliolosuhteissa.

Tulos oli, että sekä Wi-Fi että 3G-verkoissa yhteyden ylläpitäminen vie yhtä paljon energiaa kuin datan lähettäminen. Useimmissa tapauksissa jopa datan lähettäminen kulutti vähemmän energiaa kuin yhteyden ollessa tyhjäkäyntitilassa. 2G oli kertaluokkaa huonompi energiatehokkuudeltaan ja käytti paikoittain jopa 18 kertaa enemmän energiaa kuin Wi-Fi tai 3G.

Avainsanat (asiasanat)
mobiililaitteet, langaton tekniikka, energiatehokkuus

Muut tiedot

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1 Introduction

1.1 Lagging Batteries

The evolution of mobile phones over the last decade has been nothing short of phenomenal. Back in 2002 a typical mobile phone could operate up to two weeks on a single charge. Since then the introduction of large backlit colour screens, advanced operating systems and new radio technologies have had a hugely negative impact on the battery life of these devices. While the devices have become more and more powerful in computation the battery technology has not been able to keep up to accomodate the increased thirst for charge. Modern smartphones, if used actively, can hardly make it through a work day without recharging. In his book Batteries in a Portable World: A Handbook on Rechargeable Batteries for Non-Engineers the author Isidor Buchmann writes

> *The battery has not advanced at the same speeed as microelectronics, and the industry has only gained 8 to 10 percent in the last two decades. This is a far cry from Moore's Law that specifies a doubling of the number of transistors in a integrated circuit every two years. Instead of two years, the capacity of lithium-ion took 10 years to double. (Buchmann 2011.)*

In Figure 1 the evolution of cell phones can be seen. The diminishing size is partly due to batteries with higher specific energy and partry due to smaller electronic components.

Figure 1: Evolution of mobile phones (Wikipedia)

1.2 Radio Overload

A modern smartphone comes with a plethora of radio chips. Some of them are receivers only, such as FM radio and GPS, while majority of them are transceivers. GSM connectivity alone requires two to three radios. On top of that the devices typically have Wi-Fi and Bluetooth, both requiring their own radio chips. Latest top-of-the-line models come with yet another radio technology called Near Field Communication (NFC) that is thought to become a regular feature in all mobile devices within the next year or two. Figure 2 shows the printed out circuit board of a Nokia 3210 handset with several radio chips spread around the motherboard.

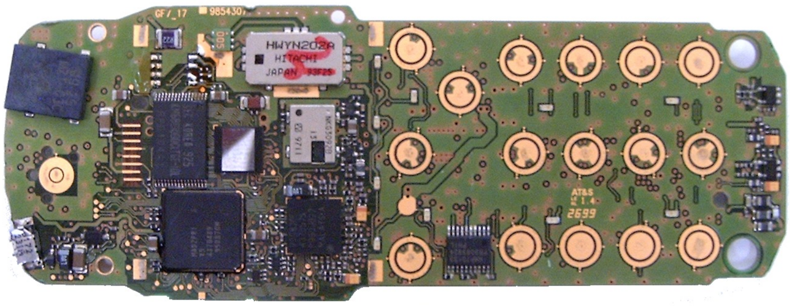

Figure 2: Stripped down view of the internal components and the several radio chips of a Nokia handset. (Wikipedia)

1.3 Energy Trap

With the emergence of LTE the mobile communications industry is growing worried about a phenomenon known as the Energy Trap. They fear that with the increased power consumption of the next generation mobile technologies the mobile devices become inceasingly immobile and the users find themselves searching for power outlets rather than network access.

1.4 Green-T

Green-T is a project trying to find ways to limit the power consumption thus prolonging the operational times of mobile devices. The project investigates the use of cooperative strategies and cognitive radios to lower power consumption while preserving proper quality of service.

Cognitive radio is a radio device that is aware of its surroundings and and the level of serivce that is required of it at any given moment. Therefore it is able to select the right connection technology considering the circumstances and either use more power for more rapid transmission speeds or preserve battery and use less bandwidth when high speeds are not needed. Reference figures of the power consumption and bandwidth capabilities of different radio technologies are needed to make those decisions.

While these tehcnologies are widely used it is difficult to find reference figures about their power consumption. This may be due to device and chip manufacturers wanting to share as little information as possible with their competitors. However, lowering the energy consumption of devices is not purely a matter of hardware design. Software must be efficient in its energy consumption to prolong battery life. Withhout reference figures such optimisation is mostly guess work.

1.5 End User Power Saving Strategies

Android operating system has many power saving features built in. The most obvious of them are the ones controlling the screen backlight. The brightness and turn-off delay can be set. The turn-off delay, however, can be overridden by software. Screen turning off while watching a video for example is not a desirable feature. Android also allows disabling data sync. This means that applications can only initiate data connections when they are running in the foreground. For example a micro blogging client will not be periodically checking for new messages.

There are also other features that have the side effect of prolonging battery life. Most drastic of them is airplane mode, which turns off all the radio chips altogether. Even though it might be hard to understand the rationale it seems to also turn off some of the chips that do not transmit anything, GPS for example. Another example is forcing the cell network connection to 2G. This will of course also slow down mobile data speed.

1.6 Programmer Power Saving Strategies

Periodically checking for new messages is quite problematic because of the potential overhead when there are no new messages to fetch. Push-to-phone technologies have been developed to remove that overhead. The radio needs to be turned on periodically for incoming messages to get through. Synchronising all traffic with those mandatory on-times reduces the need to turn on the radio thus saving energy.

2 Method

2.1 Electric Power

Power is defined as

$$P = V \cdot I \tag{1}$$

where V is voltage and I is current. Thus if we measure voltage and current we can calculate the power.

2.2 Circuit

The handsets were initially powered by a Amrel PPS-2322 programmable DC power supply. After the first day of measurements the unit broke down and was replaced by a Kenwood PD18-20D Regulated DC Power Supply. After a few days of measurements the unit was found to have a hard time delivering enough current to the handsets and it was replaced with Aplab ZS3205 Regulated DC Power Supply.

The battery was removed and the power supply connected directly to the battery terminals on the handset, effectively fooling it into thinking it was on battery power. This way there was no buffering of energy and it was possible to get real time power consumption figures. The voltage was dialed in so that it was equivalent to the battery on full charge. The nominal voltage for all devices was rated at $3.7\,\mathrm{V}$ but actual voltage at full charge varied.

A voltage meter was connected in parallel with the voltage source and the handset. An ammeter was connected in series between the positive terminal of the voltage source and the positive battery pin of the handset. The circuit in all its simplicity is laid out in Figure 3.

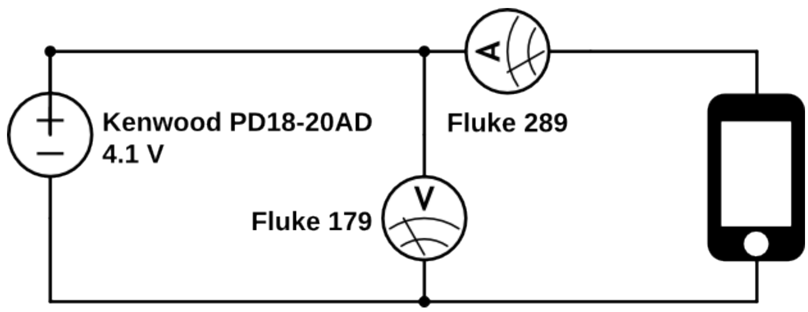

Figure 3: Circuit diagram of the measurement setup.

2.3 Hardware

2.3.1 Handsets

Three handsets were chosen for the experiment. Huawei Ideos was representing the low-cost spectrum of Android smartphone and was running the oldest Android version of the bunch. Samsung Galaxy SII, one of the most popular handsets ever made, was running Android 4.1.2. The last device chosen was Google's reference phone Nexus S running a vanilla version of Android 4.1.2. The relevant technical details of the handsets are listed in Table 1.

Table 1: Technical details of handsets. See GSM Arena for full listing.

	Huawei Ideos	Samsung Nexus S	Samsung Galaxy SII
Model	U8150	I9023	GT-I9100
CPU	528 MHz ARM 11	1 GHz Cortex-A8	Dual-core 1.2 GHz Cortex-A9
Chipset	Qualcomm MSM7225	Hummingbird	Exynos
Android version	2.2	4.1.2	4.1.2
2G frequencies	850/900/1800/1900	850/900/1800/1900	850/900/1800/1900
3G frequencies	850/900/1900/2100	900/1700/2100	850/900/1900/2100
Screen technology	TFT	S-LCD	Super AMOLED
Screen size	240x320 pixels, 2.8"	480x800 pixels, 4.0"	480x800 pixels, 4.3"
Battery	1200 mAh Li-Ion	1500 mAh Li-Ion	1650 Li-Ion

A factory reset was performed on all the handsets and a fresh Google account was used to log in. All reporting and synchonization features were turned off and services like email were not configured. For Wi-Fi measurements the handsets were not provided with a SIM card thus preventing them from connecting to cellular networks. It should be noted that even devices without SIM cards can make emergency calls. Since that capability is probably not subject to power saving measures it should not affect the findings in this study.

2.3.2 Multimeters

As described previously two multimeters were used for measuring voltage and current. Fluke 179 was user to monitor instantaneous voltage during the sessions. Fluke 179 was set on DC voltage setting and the range was set by its Auto Range feature. The manufacturer reports accuracy of 0.09%.

Fluke 289 True RMS Multimeter was used for current measurement. It was set on milliampere range and the manufacturer promises 0.06% accuracy.

2.4 Software

Handsets were equipped with software to log signal conditions during the measurements. A special build of MDO Analyzer by Versine Ltd. was used to log signal strength and saturate uplink or downlink when required. Data was then uploaded to a server for viewing. Power overhead caused by logging software was controlled by measuring the energy consumption with MDO Analyzer running in airplane mode. It should be noted that MDO Analyzer utilizes a wake lock mechanism to prevent the handset from going into power saving mode and thus interrupting logging.

2.5 Technologies

2.5.1 Wi-Fi

Wi-Fi is the name used for wireless local area networks (WLAN) that conform with the Institute of Electrical and Electronics Engineers standards IEEE 802.11x. Wi-Fi trademark is owned by the Wi-Fi Alliance organisation. Because virtually all WLAN networks are based on Wi-Fi technology, the terms Wi-Fi and WLAN have become almost synonymous. Technically, however, not all WLAN networks necessarily are Wi-Fi.

Wi-Fi is a great supplement to a mobile device, because it typically offers faster connections at a cheaper price than mobile data plans. When using private networks congestion is usually less of a problem. Typical use case for Wi-Fi is when the user is relatively stationary for longer periods at a time, such as when at home or at work.

To conserve energy, Wi-Fi should be turned off when regularly used Wi-Fi networks are out of range. This has one side effect that might not be apparent to the user. Modern smartphones use Wi-Fi acceess spot scanning to improve location data when GPS signal is not available. This might be the case when sky view is obstructed by trees, tall buldings or when indoors.

2.5.2 2G

2G is short for second generation mobile network technology. In our case the available 2G technologies are GPRS (General Packet Radio Service) and EDGE (Enhanced Data rates for GSM Evolution). Both are significant improvements over the original circuit switched 2G networks. Because they are packet switched they're sometimes refered to as 2.5G and 2.75 respectively.

2.5.3 3G

Third generation mobile network technologies are defined by the International Mobile Telecommunications-2000 (IMT-2000) specification. The technologies are based on UMTS (Universal Mobile Telecommunications System), which uses Wideband Code Division Multiple Access (WCDMA) radio access technology. Original Release '99 has since been improved upon and the evolved newer technologies sometimes denoted 3.5 are called HSPA (High Speed Packet Access).

2.6 Workflow

The battery was removed from the handset and a programmable regulated DC power source was connected to the positive and negative pins on the handsets. The voltage was adjusted to match a fully charged battery, thus eliminating any potential power saving features that might be triggered by low battery charge. Logging software was started, handset screen turned off and a measurement session was started on the Fluke 289 measuring current.

Initially the measurements were performed as a series of five minute sessions, but later on single 15 minute sessions were logged instead. This decision was made to save time by eliminating all the overhead that comes with starting an stopping a measurement session.

When the time on the Fluke 289 ran out the session was saved locally on the multimeter. Data was later extracted from the device using Fluke Forms sofware and exported as CSV (comma separated values) files. Session maximum, minimum and average values were logged in a measurement record kept in a Google Drive spreadsheet. Copy of the measurement record can be found in the appendices.

On the handset signal strength logging session was stopped and the data immediately uploaded to server and then downloaded as a database file onto a computer for local browsing. With cell network technologies the signal strength was verified using MDO Visualizer web interface.

2.7 Setups

2.7.1 Controls

Power consumption was first measured in airplane more with the screen off to measure the power consumption of the operating system when all the radios are off. Then for reference power consumption was measured with the screen on. The third control was measured with the handsets in airplane mode, screen off and Versine MDO Analyzer software running to see the impact of the logging software on the power consumption.

2.7.2 Wi-Fi

For a Wi-Fi mesurements an ad hoc access point was made out of a Android handset by using Wi-Fi hotspot connection sharing capability of the Android operating system. For measurements with good signal conditions the access point device was placed on the same table with the device under test approximately 10 cm apart. To weaken the signal the access point device was taken a couple of rooms over and put in a signal blocking pouch lines with a conductive mesh that effectively makes it a Faraday cage.

2.7.3 Mobile

For mobile network measurements Wi-Fi was turned off and the devices were provided with a SIM card. The cellular provider was DNA. For 2G the option in Androd mobile network settings to only allow 2G connections was used. Similar option for 3G was not found in the handsets, but they always connected to 3G when not explicitly told to do otherwise. For good signal conditions the device under test was simply put on the table with no arfiticial obstruction of signal reception. For bad conditions the device under test was placed in a Langer EMV-Technik ESA 1 Shielding Tent pictured in Figure 4. The Shielding tent consists of a steel plate and a conductive mesh tent that surrounds the device under test on all sides. For additional signal damping the device was placed in a signal blocking pouch. Despite all these measures, the signal damping effect was disappointingly low; only about 15-30 dBm depending on the conditions.

Figure 4: Langer EMV-Technik ESA 1 Shielding Tent (Source: langer-emv.de)

Figure 5: Signal blocking pouch with the Huawei Ideos partly immerged inside. The titanium coloured lining is the conductive mesh that makes up the Faraday cage when the pouch is sealed.

3 Results

3.1 Controls

The power consumption of the devices in airplane mode and MDO Analyzer is listed in Table 2. Controls were made with the device under test in airplane mode, then in airplane mode with the screen on and lastly in airplane mode with screen off and MDO Analyzer running.

Table 2: Power consumption with MDO Analyzer and no network connectivity.

Device	P_{airplane}	P_{screenon}	P_{analyzer}
Ideos	$63\,\text{mW} \pm 1\%$	$387\,\text{mW} \pm 1\%$	$131\,\text{mW} \pm 1\%$
Nexus S	$87\,\text{mW} \pm 1\%$	$634\,\text{mW} \pm 1\%$	$211\,\text{mW} \pm 1\%$
Galaxy SII	$50\,\text{mW} \pm 1\%$	$67\,\text{mW} \pm 1\%$	$412\,\text{mW} \pm 1\%$

3.2 Wi-Fi

3.2.1 Great Signal Conditions

Table 3 shows the results of power consumption in good Wi-Fi conditions. Great is defined in the Android source code as being $-55\,\text{dBm}$ or higher. P_{idle} is the power consumption when the device is connected to the network, but no data traffic is being generated. P_{Tx} is the power consumption when the device is sending out data as fast as possible thus saturatnig the uplink traffic. P_{Rx} is the power when the device is downloading data as fast as possible.

Table 3: Power consumption with Wi-Fi in great signal conditions.

Device	P_{idle}	P_{Tx}	P_{Rx}
Ideos	$139\,\text{mW} \pm 1\%$	$132\,\text{mW} \pm 1\%$	$146\,\text{mW} \pm 1\%$
Nexus S	$204\,\text{mW} \pm 1\%$	$204\,\text{mW} \pm 1\%$	$258\,\text{mW} \pm 1\%$
Galaxy SII	$387\,\text{mW} \pm 1\%$	$276\,\text{mW} \pm 1\%$	$577\,\text{mW} \pm 1\%$

Figure 6 shows the instantaneous current drawn by the Huawei Ideos when connected to Wi-Fi, but not transmitting data. Compare that to Figure 7 and it is easy to see that Ideos indeed uses less power then transmitting data compared to idling.

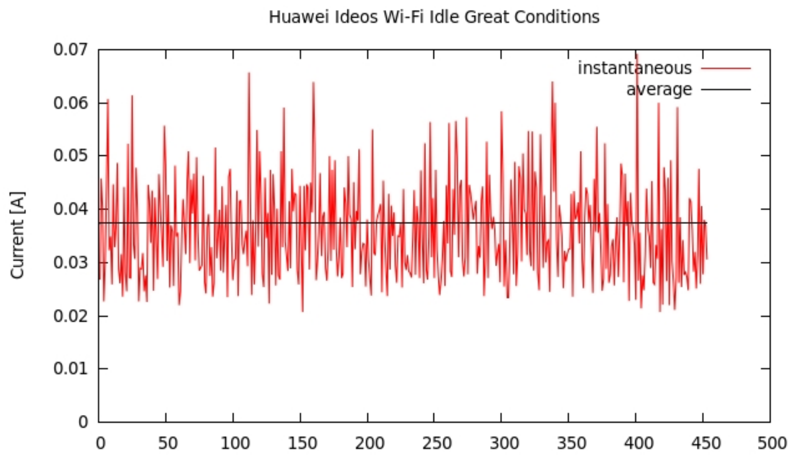

Figure 6: Current drawn by the Huawei Ideos while idling on Wi-Fi in great conditions

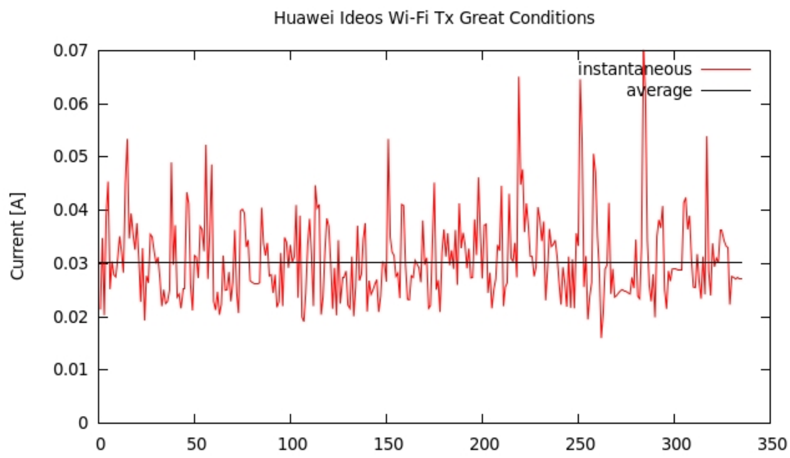

Figure 7: Current drawn by the Huawei Ideos while saturating uplink on Wi-Fi in great conditions

3.2.2 Poor Signal Conditions

Table 4 displays the results in poor or fair Wi-Fi conditions. In this case fair was defined as $-70\,\mathrm{dBm}$ to $-85\,\mathrm{dBm}$ and poor for anything below that. Again P_{idle} is the device being connected to an access point but not transmitting any data, P_{Tx} for the saturated uplink and P_{Rx} for saturated downlink.

Table 4: Power consumption with Wi-Fi in poor signal conditions.

Device	P_{idle}	P_{Tx}	P_{Rx}
Ideos	$163\,\mathrm{mW} \pm 1\%$	$174\,\mathrm{mW} \pm 1\%$	$218\,\mathrm{mW} \pm 1\%$
Nexus S	$207\,\mathrm{mW} \pm 1\%$	$362\,\mathrm{mW} \pm 1\%$	$212\,\mathrm{mW} \pm 1\%$
Galaxy SII	$377\,\mathrm{mW} \pm 1\%$	$419\,\mathrm{mW} \pm 1\%$	$400\,\mathrm{mW} \pm 1\%$

3.3 2G

3.3.1 Great Signal Conditions

Great signal conditions were defined as the phones signal strength indicator showing full bars which corresponds to signal strenth of $-81\,\mathrm{dBm}$ or better. The recorded signal strength measurements ranged from $-55\,\mathrm{dBm}$ to $-75\,\mathrm{dBm}$. In Table 5 P_{idle} is the device being connected to the network but not transmitting any data, P_{Tx} for the saturated uplink and P_{Rx} for saturated downlink.

Table 5: Power consumption with 2G in great signal conditions.

Device	P_{idle}	P_{Tx}	P_{Rx}
Ideos	$685\,\mathrm{mW} \pm 1\%$	$2360\,\mathrm{mW} \pm 1\%$	$1610\,\mathrm{mW} \pm 1\%$
Nexus S	$572\,\mathrm{mW} \pm 1\%$	$1810\,\mathrm{mW} \pm 1\%$	$1200\,\mathrm{mW} \pm 1\%$
Galaxy SII	$768\,\mathrm{mW} \pm 1\%$	$1510\,\mathrm{mW} \pm 1\%$	$1090\,\mathrm{mW} \pm 1\%$

Figure 8 illustrates the recorded signal strength for the Nexus S in good signal conditions on a 2G network.

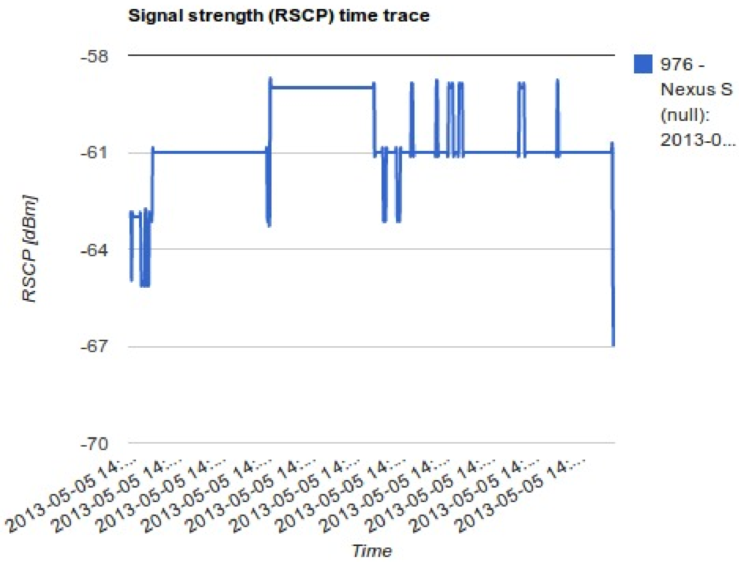

Figure 8: Nexus S idling on 2g network.

3.3.2 Damped Signal Conditions

Due to inefficient signal damping the signal strength during the damped conditions peaked as high as $-75\,\mathrm{dBm}$. On the other hand the lowest recorded value was $-95\,\mathrm{dBm}$ and by glancing at the graphs it is easy to see that on average the signal conditions were lower than in the other experiment, although nowhere near as bad as it was intended. Due to dBm being a logarithmic scale average cannot be calculated from the dBm values directly. In Table 6 P_{idle} is the device being connected to the network but not transmitting any data, P_{Tx} for the saturated uplink and P_{Rx} for saturated downlink.

Table 6: Power consumption with 2G in damped signal conditions.

Device	P_{idle}	P_{Tx}	P_{Rx}
Ideos	$606\,\mathrm{mW} \pm 1\%$	$2140\,\mathrm{mW} \pm 1\%$	$1150\,\mathrm{mW} \pm 1\%$
Nexus S	$661\,\mathrm{mW} \pm 1\%$	$1910\,\mathrm{mW} \pm 1\%$	$1250\,\mathrm{mW} \pm 1\%$
Galaxy SII	$610\,\mathrm{mW} \pm 1\%$	$1410\,\mathrm{mW} \pm 1\%$	$1110\,\mathrm{mW} \pm 1\%$

In Figure 9 you can clearly see the effect of the signal blocking tent and pouches. The signal strength starts at $-65\,\mathrm{dBm}$ and then quickly drops to below $-72\,\mathrm{dBm}$ when the tent is closed. Then at the end of the session the signal strength jumps back to $-65\,\mathrm{dBm}$ when the tent is opened and the device pulled out of the signal blocking pouch to stop the logging session.

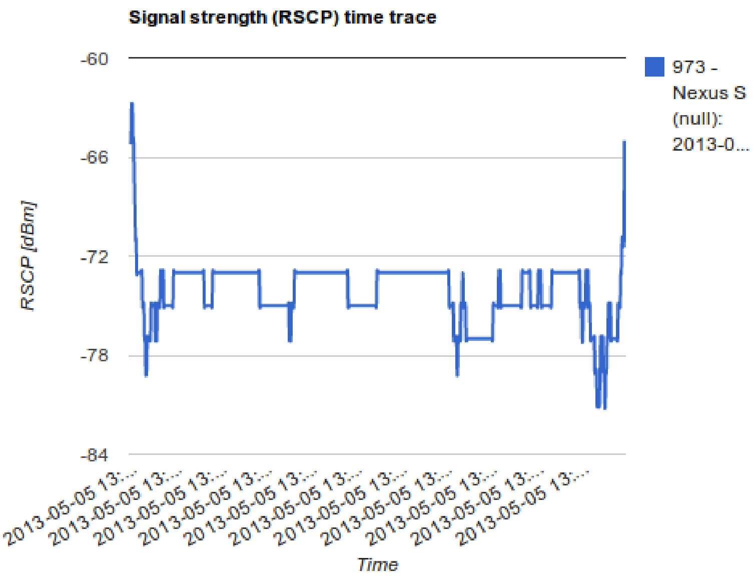

Figure 9: Nexus S idling on 2g network in damped signal conditions. The device being placed in and taken out of the Faraday cage can be seen.

3.4 3G

3.4.1 Great Signal Conditions

During the measurements with 3G in great signal conditions (defined as better than $-81\,\mathrm{dBm}$) the recorded signal strengths ranged from $-55\,\mathrm{dBm}$ to $-71\,\mathrm{dBm}$. In Table 7 P_{idle} is the device being connected to the network but not transmitting any data, P_{Tx} for the saturated uplink and P_{Rx} for saturated downlink.

Table 7: Power consumption with 3G in great signal conditions.

Device	P_{idle}	P_{Tx}	P_{Rx}
Ideos	$140\,\mathrm{mW} \pm 1\%$	$127\,\mathrm{mW} \pm 1\%$	$123\,\mathrm{mW} \pm 1\%$
Nexus S	$221\,\mathrm{mW} \pm 1\%$	$204\,\mathrm{mW} \pm 1\%$	$249\,\mathrm{mW} \pm 1\%$
Galaxy SII	$389\,\mathrm{mW} \pm 1\%$	$216\,\mathrm{mW} \pm 1\%$	$468\,\mathrm{mW} \pm 1\%$

3G signal strength on the Galaxy SII in great signal conditions is shown in Figure 10.

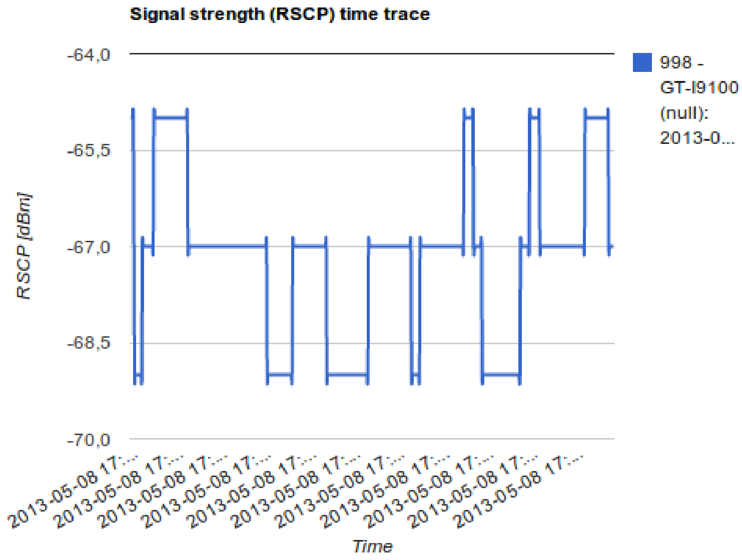

Figure 10: Galaxy SII idling on 3g network.

3.4.2 Damped Signal Conditions

Damping with 3G was just as challenging as with 2G. The signal strength ranged from $-63\,\mathrm{dBm}$ to $-83\,\mathrm{dBm}$. In Table 8 P_{idle} is the device being connected to the network but not transmitting any data, P_{Tx} for the saturated uplink and P_{Rx} for saturated downlink.

Table 8: Power consumption with 3G in damped signal conditions.

Device	P_{idle}	P_{Tx}	P_{Rx}
Ideos	$132\,\mathrm{mW} \pm 1\%$	$125\,\mathrm{mW} \pm 1\%$	$135\,\mathrm{mW} \pm 1\%$
Nexus S	$228\,\mathrm{mW} \pm 1\%$	$167\,\mathrm{mW} \pm 1\%$	$250\,\mathrm{mW} \pm 1\%$
Galaxy SII	$372\,\mathrm{mW} \pm 1\%$	$162\,\mathrm{mW} \pm 1\%$	$427\,\mathrm{mW} \pm 1\%$

Figure 11 shows again the damping effect on the signal strength. When placed inside a Farady cage the signal level drops immediately by a few decibels.

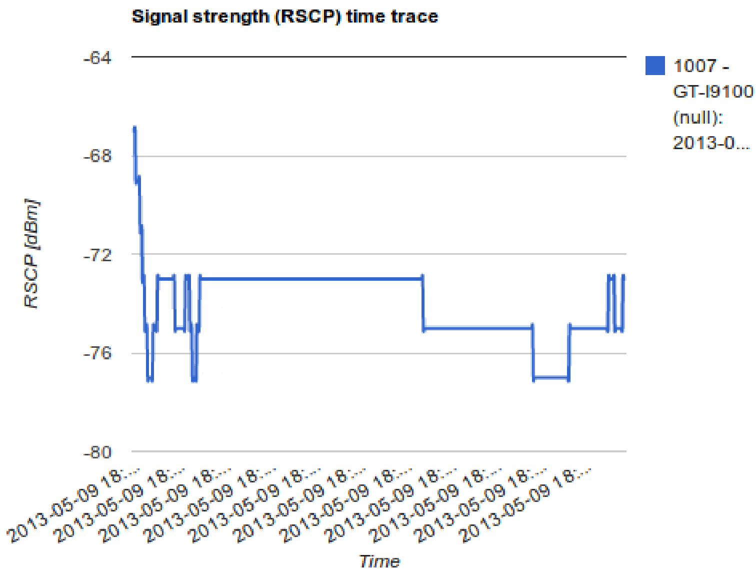

Figure 11: Galaxy SII idling on 3g network in damped signal conditions.

4 Discussion

4.1 Controls

To measure the energy consumption of the underlying operating system and the signal strength logging software a control was made with the device under test in airplane mode running the logging software. Surprisingly the energy consumption in this scenario was found to be larger than with Wi-Fi connected. It must be concluded that being in airplane mode while running MDO Analyzer makes the devices draw more power than if Wi-Fi network was available thus rendering the control useless for the purposes of isolating the power drawn by the radio chip itself.

Furthermore, the energy consumption of the Galazy SII with the screen on was found incredibly low. 17mW for backlighting a 4.3" screen does not seem credible and thus it must be concluded that something probably went wrong with that particular experiment. Due to time constraints the test was not repeated for verification.

4.2 Wi-Fi

Wi-Fi provided a surprise. It would appear that idling on Wi-Fi uses just as much power as uploading data at full speed. In fact under optimal signal conditions uploading seemed to use less power than idling. This effect was more pronounced with the Galaxy SII; however, the other handsets provided similar results.

When signal conditions were made worse the results became mixed. With Ideos all the measurements provided a little bit higher energy consumption, but with the Samsung devices downloading appeared to be using less power than under optimal conditions. This might be explained by Android's energy saving feature that seems to turn the radio off if the access point signal strenghth drops below $-90\,\mathrm{dBm}$ for an extended period of time. When that happens the operating system reports the connection status as *Temporarily avoiding poor connection* rather than as *Disconnected*. When the received signal strength dropped below $-100\,\mathrm{dBm}$ Android would disconnect immediately.

4.3 2G

Another surprise was the performance of 2G networking. Right away it was clear that the power consumption was an order of magnitude higher compared to 3G. Especially uploading under good signal conditions would use up to 18 times more power than with 3G. That combined with the lower tansmission speeds means that one might end up using over 100 times the amount energy to upload a file on 2G.

Damping the signal strenght by $20\,\mathrm{dBm}$ seemed to produce counter intuitive results with the Huawei handset. All measurements yielded lower energy usage. More detailed review of the logging data revealed that under good conditions the handset was connected using GPRS, but in the damped signal scenario it was switching between EDGE and GPRS. It could be that EDGE was the reason the total energy consumption was lower. However this was not experimentally verified due to time constraints.

In the book Batteries in a Portable World: A Handbook on Rechargeable Batteries for Non-Engineers author Isidor Buchmann writes about the progress made on lowering the energy consumption of mobile devices.

> *During the last few years, sandby and talk-times on cell phones have improved. Besides increases in the specific energy of lithium-ion, improvements in receiver and demodulator circuits have achieved notable energy savings. Figure 8-27 illustrates the reduction of power consumption in these circuits since 2002. We must keep in mind that the energy savings apply mainly to standby and receiving circuits. Transmitting still requires about five times the powere of the receiving and demodulation. (Buchmann 2011.)*

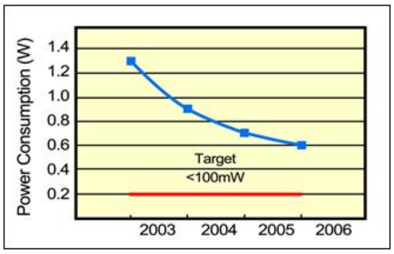

Figure 8-27: Reduction in power consumption

Cell phones have achieved notable power savings in the receiver and demodulator circuits. Transmitting needs the most power.

Source: Sieber et al. (2004).

Figure 12: Figure 8-27 from Buchmanns book Batteries in a Portable World: A Handbook on Rechargeable Batteries for Non-Engineers.

The trajectory illustrated in Figure 12 corresponds well with the results in 2G networks. However, the days when transmission used five times more power than reception are over. Even more so in 3G networks where receiving proved to be more expensive. In many cases idling on the networks used more power than transmission.

4.4 3G

3G provided results similar to Wi-Fi in the sense that idling was found to draw more power than transmitting data. Again the effect was more pronounced with Galaxy SII but appeared in all the test cases. Damping the signal strength yielded mixed results. In most cases worse signal strength resulted in lower power consumption. This might be due to poor signal damping and random variation. A more thorough study with better signal damping could not be performed due to time constraints.

4.5 Estimating Error

An error was estimated by taking into account the accuracy as reported by the multimeter manufacturer and by looking at the voltage oscillation during the measurements. It was estimated that voltage was accurate to $\pm 0.020\,\mathrm{V}$. With voltages around $4\,\mathrm{V}$ range that would correspond with the accuracy of $\pm 0.5\%$. That added with the reported accuracy of $\pm 0.06\%$ of the Fluke 289 the error of the product was estimated as being well under $\pm 1\%$.

The current measurements consisted of the average current over a data set of 900 to 1500 samples in all cases except the reference with the screen on, which only had 300 samples. When the measurements were made in multiple five minute sessions there were cases where measurements provided identical results up to four decimal places. That would suggest that the current measurement results should be quite consistent.

4.6 Signal Damping

Damping signal strength was found to be the most challenging part of the experiment. Initial tests with signal blocking pouches were promising and the devices lost all connectivity when placed in the pouch and the Faraday cage was sealed. However, it turned out that the leads that connected the DC power supply to the battery pins prevented sealing the pouch and the device was only partially covered by the conductive mesh. This did not provide the level of signal reduction that was desired. A EMS shielding tent that basically is a large Faraday cage on its own was used. The tent only reduced the signal by $10 - 20\,\mathrm{dBm}$. A few additional dBm was shaved by partially placing the device under test in signal blocking pouches inside the tent. This was nowhere near the desired level of damping of $50 - 60\,\mathrm{dBm}$. In hindsight it would have been better to find a basement of a building with bad cell reception and run the tests there instead of trying to use Faraday cages which proved highly ineffective in dampening the signal strength.

4.7 Lessons Learned

The most difficult part as explained earlier was fabricating poor signal conditions reliably.

Also logging the signal strength with minimal power overhead is something that could have used more looking into. Due to time and resource limitations more time could not be spent on modifying MDO Analyzer for this experiment.

Right now LTE is the hot topic in the mobile network industry, but the lack of available handsets and even LTE capable SIM cards excluded LTE from the study. At the time of writing this thesis the first LTE capable smartphones have hit the market in Finland and if this project was starting now LTE would probably be the main focus of the study.

One of the hardest tasks was estimating the time required for making the experiments. All kinds of unexpected obstacles kept delaying finishing up the measurements. These obstacles varied from personal time management failures to broken hardware and laboratory access problems.

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Appendices

Measurement Record

Time	Setup	Device	Voltage source setting [V]	Measured voltage [V]	Min current	Max current	Avg curent	Power consumptior	Name on Fluke	Analyzer Session	Notes
13.12.2012 19:01	Airplane mode reference	Huawei Ideos	4.1000	4.112	0.0014	0.0016	0.0015	0.006168	Recording 2		
13.12.2012 19:42	Airplane mode reference	Huawei Ideos	4.1000	4.112	0.0015	0.0016	0.0015	0.006168	Recording 3		
13.12.2012 19:48	Airplane mode reference	Huawei Ideos	4.1000	4.112	0.0014	0.0016	0.0015	0.006168	Recording 4		
13.12.2012 19:54	Airplane mode reference	Huawei Ideos	4.1000	4.112	0.0014	0.111	0.0017	0.0069904	Recording 5		
13.12.2012 19:59	Airplane mode reference	Huawei Ideos	4.1000	4.112	0.0015	0.0016	0.0015	0.006168	Recording 6		
13.12.2012 20:11	Airplane mode reference	Samsung Nexus S	4.1950	4.211	0.0015	0.1411	0.002	0.008422	Recording 7		Something was drawing a suspicious amount of current in the beginning of the measurement
13.12.2012 20:17	Airplane mode reference	Samsung Nexus S	4.1950	4.211	0.0014	0.15	0.002	0.008422	Recording 8		Similar spike in this one too
13.12.2012 20:24	Airplane mode reference	Samsung Nexus S	4.1950	4.211	0.0015	0.0049	0.0017	0.0071587	Recording 9		
13.12.2012 20:29	Airplane mode reference	Samsung Nexus S	4.1950	4.211	0.0015	0.1696	0.0019	0.0080009	Recording 10		
13.12.2012 20:34	Airplane mode reference	Samsung Nexus S	4.1950	4.211	0.0015	0.2113	0.0027	0.0113697	Recording 11		
13.12.2012 20:40	Screen on & Airplane mode	Samsung Nexus S	4.1950	4.206	0.1492	0.2207	0.1508	0.6342648	Recording 12		
13.12.2012 20:50	Screen on & Airplane mode	Huawei Ideos	4.1000	4.109	0.0806	0.1704	0.0941	0.3866569	Recording 13		
13.04.2013 17:37	Screen off, airplane & analyzer	Huawei Ideos	4.1000	4.112	0.0153	0.0517	0.0303	0.1245936	Recording 14		Profile: Mobile signal strength only, no SIM
13.04.2013 17:43	Screen off, airplane & analyzer	Huawei Ideos	4.1000	4.112	0.014	0.0506	0.029	0.119248	Recording 15		Profile: Mobile signal strength only, no SIM
13.04.2013 17:54	Screen off, airplane & analyzer	Huawei Ideos	4.1000	4.112	0.0142	0.0488	0.028	0.115136	Recording 16		Profile: Mobile signal strength only, no SIM
13.04.2013 18:00	Screen off, airplane & analyzer	Huawei Ideos	4.1000	4.112	0.0165	0.052	0.029	0.119248	Recording 17		Profile: Mobile signal strength only, no SIM
13.04.2013 18:06	Screen off, airplane & analyzer	Huawei Ideos	4.1000	4.112	0.0158	0.0498	0.0263	0.1081456	Recording 18		Profile: Mobile signal strength only, no SIM
13.04.2013 19:24	Screen off, airplane & analyzer	Samsung Nexus S	4.1950	4.211	0.012	0.1114	0.048	0.202128	Recording 19		Profile: Mobile signal strength only, no SIM
13.04.2013 19:30	Screen off, airplane & analyzer	Samsung Nexus S	4.1950	4.211	0.0133	0.1063	0.0495	0.2084445	Recording 20		Profile: Mobile signal strength only, no SIM
13.04.2013 19:36	Screen off, airplane & analyzer	Samsung Nexus S	4.1950	4.211	0.0134	0.1084	0.0507	0.2134977	Recording 21		Profile: Mobile signal strength only, no SIM
13.04.2013 19:46	Screen off, airplane & analyzer	Samsung Nexus S	4.1950	4.211	0.0102	0.1115	0.0512	0.2156032	Recording 22		Profile: Mobile signal strength only, no SIM
13.04.2013 19:52	Screen off, airplane & analyzer	Samsung Nexus S	4.1950	4.211	0.0087	0.1101	0.0513	0.2160243	Recording 23		Profile: Mobile signal strength only, no SIM
14.04.2013 12:35	Wi-fi idle great	Huawei Ideos	4.08	4.113	0.0185	0.0894	0.0355	0.1460115	Recording 24	postdata-1365932097	New DC power supply!
14.04.2013 12:44	Wi-fi idle great	Huawei Ideos	4.08	4.113	0.0191	0.0942	0.0374	0.1538262	Recording 25	postdata-1365932838	

Time	Setup	Device	Voltage source setting [V]	Measured voltage [V]	Min current	Max current	Avg curent	Power consumptior	Name on Fluke	Analyzer Session	Notes
14.04.2013 12:56	Wi-fi idle great	Huawei Ideos	4.08	4.113	0.0161	0.08	0.0333	0.1369629	Recording 26	postdata-1365933449	
14.04.2013 13:06	Wi-fi idle great	Huawei Ideos	4.08	4.113	0.0186	0.0764	0.0322	0.1324386	Recording 27	postdata-1365934118	
14.04.2013 13:14	Wi-fi idle great	Huawei Ideos	4.08	4.113	0.0166	0.0734	0.0309	0.1270917	Recording 28	postdata-1365934499	
14.04.2013 14:24	Wi-fi TX great	Huawei Ideos	4.08	4.113	0.016	0.0703	0.0301	0.1238013	Recording 29	postdata-1365938749	
14.04.2013 14:31	Wi-fi TX great	Huawei Ideos	4.08	4.113	0.0156	0.0812	0.0288	0.1184544	Recording 30	postdata-1365939232	
14.04.2013 14:39	Wi-fi TX great	Huawei Ideos	4.08	4.113	0.0164	0.0774	0.0337	0.1386081	Recording 31	postdata-1365939605	
14.04.2013 14:46	Wi-fi TX great	Huawei Ideos	4.08	4.113	0.0169	0.0779	0.0338	0.1390194	Recording 32	postdata-1365940031	
14.04.2013 14:54	Wi-fi TX great	Huawei Ideos	4.08	4.113	0.0184	0.0752	0.0344	0.1414872	Recording 33	postdata-1365940493	
14.04.2013 15:00	Wi-fi RX great	Huawei Ideos	4.08	4.113	0.0196	0.0685	0.036	0.148068	Recording 34	postdata-1365940869	
14.04.2013 15:07	Wi-fi RX great	Huawei Ideos	4.08	4.113	0.0191	0.0627	0.0347	0.1427211	Recording 35	postdata-1365941255	
14.04.2013 15:16	Wi-fi RX great	Huawei Ideos	4.08	4.113	0.0195	0.0708	0.036	0.148068	Recording 36	postdata-1365941836	
14.04.2013 16:54	Wi-fi idle poor	Huawei Ideos	4.08	4.113	0.0168	0.0653	0.029	0.119277	Recording 37		Analyzer ei toiminut
14.04.2013 17:09	Wi-fi idle poor	Huawei Ideos	4.08	4.113	0.0157	0.068	0.0288	0.1184544	Recording 38		
14.04.2013 18:18	Wi-fi idle poor	Huawei Ideos	4.08	4.113	0.0167	0.0737	0.0314	0.1291482	Save 2	postdata-1365952836	
24.04.2013 18:11	Wi-fi idle great	Samsung Nexus S	4.16	4.212	0.013	0.1135	0.0497	0.2093364	Recording 39		
25.04.2013 17:38	Wi-fi idle great	Samsung Nexus S	4.19	4.212	0.0136	0.1091	0.0495	0.208494	Recording 40	postdata-1366900687	
25.04.2013 17:45	Wi-fi idle great	Samsung Nexus S	4.19	4.212	0.0135	0.1142	0.0464	0.1954368	Recording 41	postdata-1366901237	
25.04.2013 17:59	Wi-fi TX great	Samsung Nexus S	4.19	4.212	0.0139	0.1823	0.0409	0.1722708	Recording 42	postdata-1366902029	
25.04.2013 18:06	Wi-fi TX great	Samsung Nexus S	4.19	4.212	0.0152	0.171	0.0526	0.2215512	Recording 43	postdata-1366902478	
25.04.2013 18:15	Wi-fi TX great	Samsung Nexus S	4.19	4.212	0.0139	0.1386	0.0516	0.2173392	Recording 44	postdata-1366902941	
25.04.2013 18:32	Wi-fi RX great	Samsung Nexus S	4.19	4.212	0.0122	0.2111	0.0581	0.2447172	Recording 45	postdata-1366903980	
25.04.2013 18:41	Wi-fi RX great	Samsung Nexus S	4.19	4.212	0.0175	0.2146	0.0756	0.3184272	Recording 46	postdata-1366904454	
25.04.2013 18:49	Wi-fi RX great	Samsung Nexus S	4.19	4.212	0.0127	0.2013	0.0503	0.2118636	Recording 47	postdata-1366905060	May have disconnected from Wifi during the session
25.04.2013 19:35	Wi-fi idle poor	Samsung Nexus S	4.19	4.212	0.0147	0.1133	0.0483	0.2034396	Save 3	postdata-1366909000	
25.04.2013 19:42	Wi-fi idle poor	Samsung Nexus S	4.19	4.212	0.0148	0.1096	0.0507	0.2135484	Recording 48	postdata-1366909000	Disconnected

Time	Setup	Device	Voltage source setting [V]	Measured voltage [V]	Min current	Max current	Avg curent	Power consumptior	Name on Fluke	Analyzer Session	Notes
25.04.2013 19:50	Wi-fi idle poor	Samsung Nexus S	4.19	4.212	0.015	0.1289	0.0545	0.229554	Recording 49	postdata-1366909000	Disconnected
28.04.2013 12:03	~~3G idle great~~	~~Huawei Ideos~~	~~3.99~~	~~4.112~~				0			~~Vituix, ei APN-asetuksia~~
28.04.2013 12:35	3G idle great	Huawei Ideos	3.97	4.111	0.0192	0.0812	0.034	0.139774	Recording 51	postdata-1367142145	
28.04.2013 12:35	3G TX great	Huawei Ideos	3.97	4.111	0.0222	0.044	0.031	0.127441	Recording 52	postdata-1367143322	
28.04.2013 13:10	3G RX great	Huawei Ideos	3.97	4.111	0.0231	0.454	0.03	0.12333	Recording 53	postdata-1367144354	
28.04.2013 14:43	3G idle reduced	Huawei Ideos	3.97	4.111	0.0182	0.0752	0.032	0.131552	Recording 54	postdata-1367149994	http://versine.eu/demo/list.php?seq=939
28.04.2013 15:04	3G TX reduced	Huawei Ideos	3.97	4.111	0.0208	0.1069	0.0303	0.1245633	Recording 55	postdata-1367151292	http://versine.eu/demo/list.php?seq=940
28.04.2013 15:04	3G RX reduced	Huawei Ideos	3.97	4.111	0.0182	0.0757	0.0328	0.1348408	Recording 56	postdata-1367152862	http://versine.eu/demo/list.php?seq=941
28.04.2013 15:56	2G idle reduced	Huawei Ideos	3.97	4.111	0.0166	0.5763	0.1473	0.6055503	Recording 57	postdata-1367154524	http://versine.eu/demo/list.php?seq=942
28.04.2013 16:16	2G TX reduced	Huawei Ideos	3.97	4.11	0.0285	0.5444	0.5197	2.135967	Recording 58	postdata-1367155770	http://versine.eu/demo/list.php?seq=943
28.04.2013 16:36	2G RX reduced	Huawei Ideos	3.97	4.111	0.0235	0.5482	0.28	1.15108	Recording 59	postdata-1367156869	http://versine.eu/demo/list.php?seq=944
28.04.2013 18:35	2G idle great	Huawei Ideos	3.97	4.111	0.019	0.5866	0.1666	0.6848926	Recording 60	postdata-1367164049	http://versine.eu/demo/list.php?seq=945
28.04.2013 19:04	2G TX great	Huawei Ideos	3.97	4.111	0.4256	0.6036	0.575	2.363825	Recording 61	postdata-1367164049	http://versine.eu/demo/list.php?seq=946
28.04.2013 19:55	2G RX great	Huawei Ideos	3.97	4.111	0.2271	0.4575	0.3906	1.6057566	Recording 62	postdata-1367169254	Analyzer-data mättää
28.04.2013 20:26	3G idle great	Samsung Nexus S	4.2	4.212	0.0104	0.1202	0.0524	0.2207088	Recording 63	postdata-1367170661	http://versine.eu/demo/list.php?seq=948
28.04.2013 21:08	3G TX great	Samsung Nexus S	4.2	4.212	0.0145	0.116	0.0485	0.204282	Recording 64	postdata-1367173135	http://versine.eu/demo/list.php?seq=949
28.04.2013 21:27	3G RX great	Samsung Nexus S	4.2	4.212	0.0182	0.1179	0.0592	0.2493504	Recording 65	postdata-1367174169	
05.05.2013 11:25	2G RX great	Huawei Ideos	4.08	4.111				0			Huawei buuttasi kesken mittauksen
05.05.2013 12:05	2G RX great	Huawei Ideos	4	4.111	0.0118	0.4773	0.4003	1.6456333	Recording 66	postdata-1367745452	Uusi jännitelähde Aplab, jätä viimeinen minuutti pois virtamittauksesta, http://versine.eu/demo/list.php?seq=969
05.05.2013 13:46	3G idle reduced	Samsung Nexus S	4.1	4.207	0.0171	0.1162	0.0541	0.2275987	Recording 67	postdata-1367751489	http://versine.eu/demo/list.php?seq=970
05.05.2013 14:06	3G TX reduced	Samsung Nexus S	4.1	4.207	0.0156	0.1167	0.0397	0.1670179	Recording 68	postdata-1367752591	http://versine.eu/demo/list.php?seq=971
05.05.2013 14:24	3G RX reduced	Samsung Nexus S	4.1	4.207	0.0121	0.1883	0.0594	0.2498958	Recording 69	postdata-1367753646	http://versine.eu/demo/list.php?seq=972
05.05.2013 14:41	2G idle reduced	Samsung Nexus S	4.1	4.209	0.0242	0.5269	0.157	0.660813	Recording 70	postdata-1367754731	http://versine.eu/demo/list.php?seq=973
05.05.2013 15:00	2G TX reduced	Samsung Nexus S	4.1	4.202	0.2439	0.4834	0.4541	1.9081282	Recording 71	postdata-1367755832	http://versine.eu/demo/list.php?seq=974

Time	Setup	Device	Voltage source setting [V]	Measured voltage [V]	Min current	Max current	Avg curent	Power consumptior	Name on Fluke	Analyzer Session	Notes
05.05.2013 15:17	2G RX reduced	Samsung Nexus S	4.1	4.208	0.0286	0.5638	0.2977	1.2527216	Recording 72	postdata-1367756880	http://versine.eu/demo/list.php?seq=975
05.05.2013 15:39	2G idle great	Samsung Nexus S	4.1	4.212	0.0253	0.4562	0.1359	0.5724108	Recording 73	postdata-1367758182	http://versine.eu/demo/list.php?seq=976
05.05.2013 15:57	2G TX great	Samsung Nexus S	4.1	4.206	0.0273	0.4856	0.4303	1.8098418	Recording 74	postdata-1367759191	http://versine.eu/demo/list.php?seq=977
05.05.2013 16:13	2G RX great	Samsung Nexus S	4.1	4.21	0.0424	0.3819	0.285	1.19985	Recording 75		
05.05.2013 19:44	Airplane mode reference	Samsung Galaxy SII	4.1	4.21	0.0085	0.014	0.0118	0.049678	Recording 76		
05.05.2013 20:00	Screen on & Airplane mode	Samsung Galaxy SII	4.1	4.207	0.0105	0.1572	0.016	0.067312	Recording 77		
05.05.2013 20:09	Screen off, airplane & analyzer	Samsung Galaxy SII	4.1	4.207	0.0157	0.2812	0.0981	0.4127067	Recording 78		
06.052013 17:41	Wi-fi idle great	Samsung Galaxy SII	4.2	4.211	0.0078	0.2914	0.092	0.387412	Recording 79	postdata-1367851886	
06.052013 17:58	Wi-fi TX great	Samsung Galaxy SII	4.2	4.211	0.016	0.2839	0.0657	0.2766627	Recording 80	postdata-1367852890	
06.05.2013 18:15	Wi-fi RX great	Samsung Galaxy SII	4.2	4.211	0.0183	0.3408	0.137	0.576907	Recording 81	postdata-1367853941	
06.05.2013 18:41	Wi-fi idle poor	Samsung Galaxy SII	4.2	4.211	0.0089	0.3027	0.0895	0.3768845	Recording 82	postdata-1367855443	one bar or "fair"
06.05.2013 18:57	Wi-fi TX poor	Samsung Galaxy SII	4.2	4.211	0.0115	0.3258	0.0994	0.4185734	Recording 83	postdata-1367856448	
06.05.2013 19:14	Wi-fi RX poor	Samsung Galaxy SII	4.2	4.211	0.0136	0.2956	0.0951	0.4004661	Recording 84	postdata-1367857490	
08.05.2013 17:17	3G idle great	Samsung Galaxy SII	4.2	4.209	0.0153	0.2623	0.0936	0.3939624	Recording 85	postdata-1368023199	http://versine.eu/demo/list.php?seq=995
08.05.2013 17:33	3G TX great	Samsung Galaxy SII	4.2	4.209	0.0128	0.2676	0.0606	0.2550654	Recording 86	postdata-1368024238	http://versine.eu/demo/list.php?seq=996
08.05.2013 17:50	3G RX great	Samsung Galaxy SII	4.2	4.209	0.0206	0.2863	0.106	0.446154	Recording 87	postdata-1368025196	Wi-Fi jäi päälle!
08.05.2013 18:13	3G idle great	Samsung Galaxy SII	4.2	4.209	0.0081	0.2717	0.0924	0.3889116	Recording 88	postdata-1368026542	http://versine.eu/demo/list.php?seq=998
08.05.2013 18:28	3G TX great	Samsung Galaxy SII	4.2	4.209	0.0089	0.261	0.0514	0.2163426	Recording 89	postdata-1368027564	http://versine.eu/demo/list.php?seq=999
08.05.2013 18:44	3G RX great	Samsung Galaxy SII	4.2	4.209	0.0152	0.3494	0.1113	0.4684617	Recording 90	postdata-1368028590	http://versine.eu/demo/list.php?seq=1000
08.05.2013 19:04	2G idle great	Samsung Galaxy SII	4.2	4.209	0.0254	0.447	0.1825	0.7681425	Recording 91	postdata-1368029612	http://versine.eu/demo/list.php?seq=1001
08.05.2013 19:20	2G TX great	Samsung Galaxy SII	4.2	4.2	0.0511	0.5529	0.3587	1.50654	Recording 92	postdata-1368030635	http://versine.eu/demo/list.php?seq=1002
08.05.2013 19:37	2G RX great	Samsung Galaxy SII	4.2	4.2	0.1176	0.3972	0.26	1.092	Recording 93	postdata-1368031637	http://versine.eu/demo/list.php?seq=1003
09.05.2013 18:34	2G idle reduced	Samsung Galaxy SII	4.2	4.2	0.0295	0.3231	0.1453	0.61026	Recording 94	postdata-1368114284	http://versine.eu/demo/list.php?seq=1004
09.05.2013 18:55	2G TX reduced	Samsung Galaxy SII	4.2	4.2	0.1236	0.5078	0.3366	1.41372	Recording 95	postdata-1368115518	http://versine.eu/demo/list.php?seq=1005
09.05.2013 19:12	2G RX reduced	Samsung Galaxy SII	4.2	4.2	0.0589	0.4389	0.2654	1.11468	Recording 96	postdata-1368116552	http://versine.eu/demo/list.php?seq=1006

Time	Setup	Device	Voltage source setting [V]	Measured voltage [V]	Min current	Max current	Avg curent	Power consumptior	Name on Fluke	Analyzer Session	Notes
09.05.2013 19:31	3G idle reduced	Samsung Galaxy SII	4.2	4.207	0.0117	0.3369	0.0884	0.3718988	Recording 97	postdata-1368117655	http://versine.eu/demo/list.php?seq=1007
09.05.2013 19:49	3G TX reduced	Samsung Galaxy SII	4.2	4.207	0.0091	0.2799	0.0384	0.1615488	Recording 98	postdata-1368118756	http://versine.eu/demo/list.php?seq=1008
09.05.2013 20:06	3G RX reduced	Samsung Galaxy SII	4.2	4.207	0.0144	0.2971	0.1016	0.4274312	Recording 99	postdata-1368119784	http://versine.eu/demo/list.php?seq=1009
10.05.2013 15:37	Wi-fi idle poor	Huawei Ideos	4.1	4.105	0.0189	0.0939	0.0396	0.162558	Save 4	postdata-1368190099	
10.05.2013 15:56	Wi-fi TX poor	Huawei Ideos	4.1	4.105	0.0177	0.1758	0.0425	0.1744625	Save 5	postdata-1368191282	
10.05.2013 16:15	Wi-fi RX poor	Huawei Ideos	4.1	4.105	0.0161	0.1199	0.053	0.217565	Save 6	postdata-1368192380	
10.05.2013 16:55	Wi-fi idle poor	Samsung Nexus S	4.2	4.212	0.0109	0.1251	0.0492	0.2072304	Save 7	postdata-1368194708	
10.05.2013 17:12	Wi-fi TX poor	Samsung Nexus S	4.2	4.212	0.0119	0.2505	0.086	0.362232	Save 8	postdata-1368195718	
10.05.2013 17:31	Wi-fi RX poor	Samsung Nexus S	4.2	4.212	0.0116	0.1489	0.0503	0.2118636	Save 9		

Controls

Device	Airplane mode	Screen on	MDO Analyzer
Huawei Ideos	0.00633248	0.3866569	0.131416533333333
Samsung Nexus S	0.00867466	0.6342648	0.21113954
Samsung Galaxy SII	0.049678	0.067312	0.4127067

Wi-Fi great

	Idle	Tx	Rx
Huawei Ideos	0.13926618	0.13227408	0.1462857
Samsung Nexus S	0.2044224	0.2037204	0.258336
Samsung Galaxy SII	0.387412	0.2766627	0.576907

Wi-Fi reduced

	Idle	Tx	Rx
Huawei Ideos	0.162558	0.1744625	0.217565
Samsung Nexus S	0.2072304	0.362232	0.2118636
Samsung Galaxy SII	0.3768845	0.4185734	0.4004661

2G great

	Idle	Tx	Rx
Huawei Ideos	0.6848926	2.363825	1.6057566
Samsung Nexus S	0.5724108	1.8098418	1.19985
Samsung Galaxy SII	0.7681425	1.50654	1.092

2G reduced

	Idle	Tx	Rx
Huawei Ideos	0.6055503	2.135967	1.15108
Samsung Nexus S	0.660813	1.9081282	1.2527216
Samsung Galaxy SII	0.61026	1.41372	1.11468

	3G great			
		Idle	Tx	Rx
	Huawei Ideos	0.139774	0.127441	0.12333
	Samsung Nexus S	0.2207088	0.204282	0.2493504
	Samsung Galaxy SII	0.3889116	0.2163426	0.4684617
	3G reduced			
		Idle	Tx	Rx
	Huawei Ideos	0.131552	0.1245633	0.1348408
	Samsung Nexus S	0.2275987	0.1670179	0.2498958
	Samsung Galaxy SII	0.3718988	0.1615488	0.4274312